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Flood Vulnerability Mapping using Geospatial Techniques: Case Study of Lagos State, Nigeria

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ABSTRACT

Flood is one of the natural disaster known to be part of the earth biophysical processes, which its occurrence can be devastating; due to mostly anthropogenic activities and climatological factors. The aim of the research is to identify and map the extent at which the impact of flood due to intense rainfall and rise in water in the study area using geospatial techniques and the specific objectives are to carry out terrain analysis of the study area and to generate flood indicator maps of the study area. The study analyzed rain fall data;, the drainage system and Shuttle Radar Topographic Mission (SRTM 30m) of the area. ArcGIS 10.8 was to modelled and to generate the contributing factors map of the study area. The drainage system was generated through on-screen digitization of topographic map of scale 1:50,000 of Ondo South-West. The mean annual rainfall of Lagos State was generated in the ArcGIS environment from the rainfall data through spatial analysis tool. The SRTM was used in terrain analysis of the study area. The results generated showed the lowest mean annual rain fall of the area 1,700mm and the highest mean annual rain fall was 2,440mm. Digital elevation model (DEM), slope, flow direction were generated from the SRTM. Drainage density of the area was generated using the drainage system. The slope map of the entire area which are classified into five slope classes of very high (14%-48.5%) to high (7.6%-13.9%) to moderately high (4.2%-7.6%) to low (1.5%-4.2%) and very low (0. % - 1.2%).

Keywords: *Climate change; Hazard; Geospatial techniques; DEM; Flood; Sea level rise.*

1. INTRODUCTION

Those circumstances that are determined by physical , social , economic, and environmental factors or processes that increase a location's (city or community) susceptibility to the impact of the danger is called vulnerability. In other words, vulnerability is a collection of prevailing conditions that adversely affect the ability of the community to avoid, mitigate, plan or respond to a danger (Alwang et al., 2001).

Physical vulnerability depends on its geographical proximity to the source and origin of the disaster, for example if a region lies near the sea, Industrial region (unfavorable atmospheric condition), area near the fault line, all these area are more susceptible to disasters Charvériat, C. (2007 compared with an environment which is far from the sources of the disaster.

In addition, the poor design and construction of residential and commercial buildings results in weaker and more vulnerable to earthquakes, flooding, ground slides and other hazards.

The consequences of climate and environmental change, such as rising temperatures, rising sea levels, shifting precipitation patterns and more serious extreme weather events are expected to affect key determinants of human health, including access to clean water, adequate food and adequate shelter. These effects may also aggravate political and civil conflicts directly and indirectly; destabilize agriculture, housing, and economies; and exacerbate health threats to vulnerable communities, especially women and children.

The social destabilization caused by drought, floods, famine and crises, including pandemics such as COVID-19, can intensify political and civil conflicts as those affected are competing for the same resources. Tackling these issues includes cross-border, national and multi-sectorial teamwork.

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2. MATERIALS AND METHODOLOGY

2.1. Study Area

Lagos State is situated closely to the Atlantic ocean, , the cost extend from Badagry to Ogun state about 180 km long and inland to a distance of about 32 km, 17 per cent of the state consist of lagoons, creeks and coastal estuaries (Adefuye et al . , 2002; Onyekwelu et al., 2003).The geographical location of the state lies approximately between longitudes 20 42 / E to 30 42/ E and latitudes 60 22/ N to 60 42/ N (Akinsanya, 2003; Onyekwelu et al., 2003). Lagos state is one of the smallest states in Nigeria, with only 0.4 % of the total land mas, with the highest number of industries and it is the commercial city of Nigeria.

The coastal city of Lagos, the leading port city in West Africa and second largest metropolitan city in Africa.. Lagos also accounts for more than 70 percent of the country's maritime cargo and seaport activities, and 80 percent of the country's international air traffic., Lagos has risen by 2,129,126, reflecting an annual improvement of 3.26 per cent, with the city's population expected to reach 20 million by 2030 (National Population Commission Nigeria, 2019). The growing population is mainly due to the concentration of economic activities in the city. The population density is around 6,871 people per square / km2 (National Statistics Bureau, 2019) much exceeds the global average population density for coastal zones of 112 persons / km2 (IHDP, 2012).

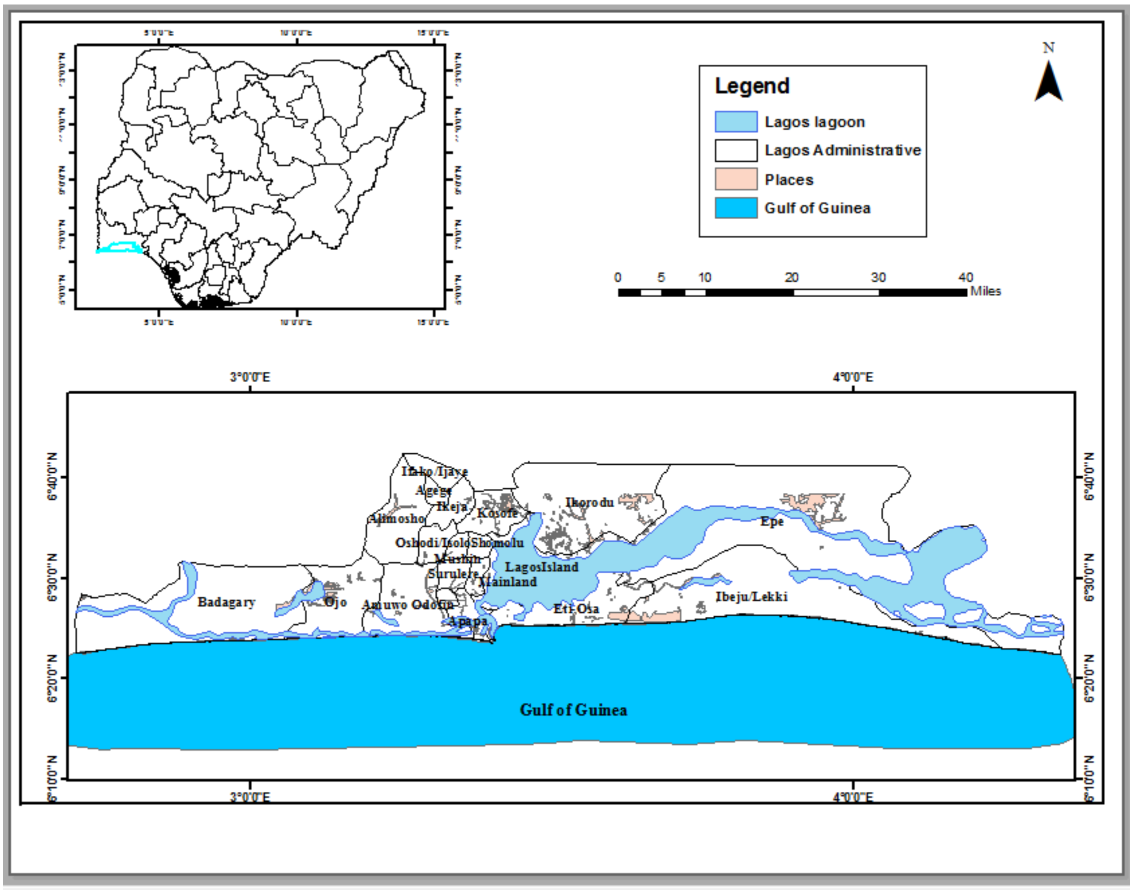

Figure 1. Study area map

High percentage of Lagos' population lives in slums. By 2070, Lagos is predicted to rank fifth among the city's most vulnerable to climate change threats (Nicholls et al., 2007b). A Climate Change Vulnerability Index listed

Lagos as one of the top 10 global cities and Africa's only city with a 'high risk' from climate change (Maple Croft, 2012). The growing severity and influence of both inland and coastal floods is a significant consequence of climate change at Lagos (Adelekan, 2010; Young, 2013).

The soft wares used in this research are:

(1) ArcGIS 10.8 version, (2) Microsoft office visio 2007, (3) Microsoft office word.

Table 1. Summary of Data used

Data	Data extracted	Attributes	Source
Rainfall	Mean annual rain fall	30years predicted value	NASA
SRTM	Slope, Elevation and flow accumulation	30m	USGS
GPS	Ground control points		

The Digital elevation model (DEM) of the study area was imported into the ArcGIS environment, projected to WGS 1984, zone 31 and in degrees, minutes and seconds. The map was georeferenced and updated, on-screen digitization was done on the topographic map to extract the drainage. Spatial hydrological processes was performed to generate the flow accumulation of the study area. Shuttle Radar Topographic Mission was cleaned and filled using focal statistic in the spatial analyst tools before further analysis was done. The shape file of the study area was overlaid on the SRTM and clipped to generate the slope, digital elevation model and the drainage density of the study area. The rain fall data was imported to the Arc map environment and converted to point data and interpolated. The point data was projected to the working environment, spatial analysis of inverse distance weighted (IDW) was done to produce the mean annual rainfall of the study area. All the participating factors were reclassified to raster and saved in the database. Weighted sum analysis was performed to generate the vulnerability map of the area and the vulnerability was grouped into four in order of severity. To delineate the flood zone, "bathtub" model was adopted, an approach often called the "single-value surface" (National Oceanic and Atmospheric Administration [NOAA], 2010), "equilibrium" (Gallien et al., 2011), "planar" (Bates and De Roo, 2000), "hydrostatic" (Habel et al., 2017), and "static inundation" (Paprotny et al., 2018) method. To achieve this, a scenario was created by raising the water level by 2m and 5m respectively on a coastal digital elevation model (DEM) to select all areas below the new water level.

3. RESULTS AND DISCUSSION

3.1. Slope

The inundation of an area depends on the length and steepness of its slope. For instance, areas with low slope length and angle will experience inundation compared to areas with high slope length and angle (Mishra & Sinha, 2020). The slope of the area under investigation ranges between minimum of 0% to maximum of 48.5%. Figure 1 shows the slope map of the entire area which are classified into five slope classes of very high (14%-48.5%) to high

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(7.6%-13.9%) to moderately high (4.2%-7.6%) to low (1.5%-4.2%) and very low (0. % - 1.2%). It worth noting that almost the whole area is relatively low which renders it more prone to flooding events and the impact of rise in sea level. This is evident in area such as Victoria Island and Lekki area. This could be the sole reason why these area is prone to recurring flooding events.

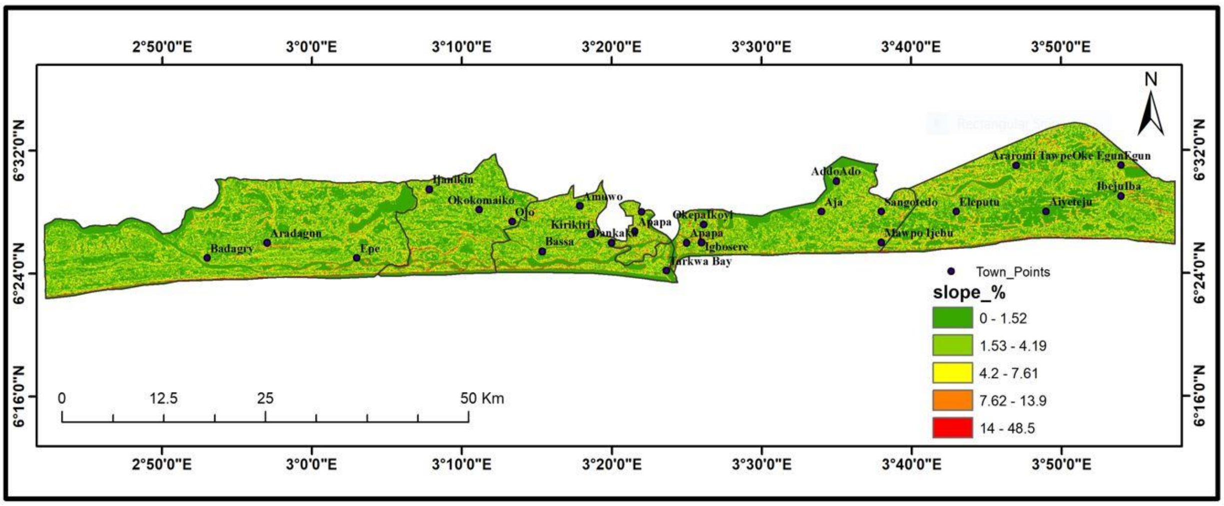

Figure 2. Slope of the study area

3.2. Drainage Density

High drainage density signifies high surface runoff generation and therefore higher likelihood of flooding, and vice versa (Mahmoud & Gan, 2018; Danumah et al., 2016). High drainage densities means greater runoff rates and hence, high flood susceptibility (Radwan et al., 2018; Danumah et al., 2016). Figure 2 shows the drainage density map of the study area. The drainage density map is classified into five density classes namely, very high, high, medium, low, and very low. Very high drainage densities were found mostly in the commercial areas, main road and agricultural lands, while very low drainage densities were found in bared land and areas that lacks vegetation. Very high drainage density class ranges from (0.00639 - 0.00797 km/km^2), which means very high flood hazard, high (0.00479 - 0.00639km/km^2), moderate (0.0032 - 0.00478km/ km^2), low (0.016 - 0.00319 km/km^2), and very low (0 - 0.0159km/km2) drainage densities.

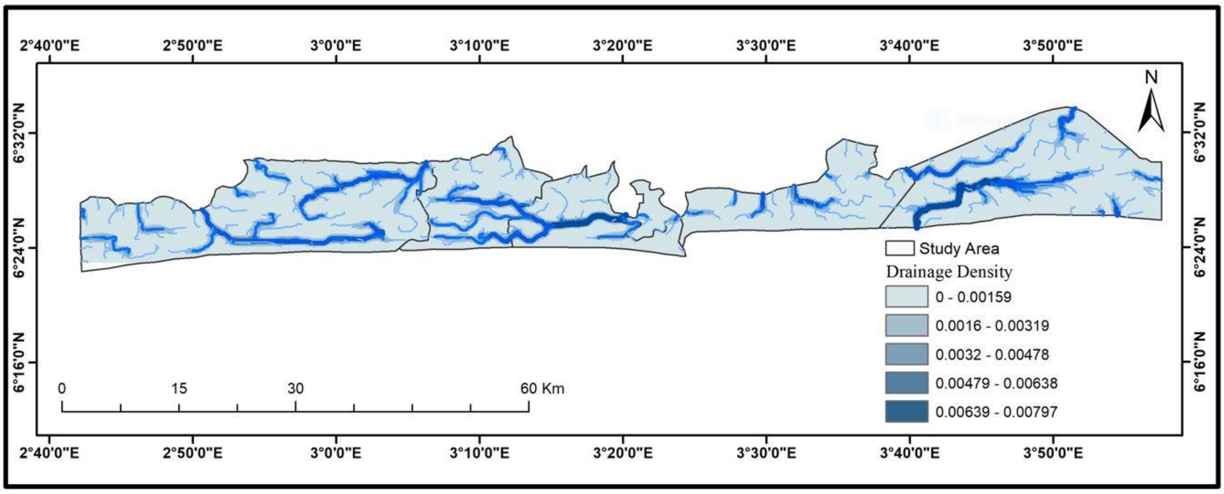

Figure 3. Drainage Density Map of the study area

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3.3. Flow Accumulation

The flow accumulation was considered as one of the contributing indicator of flood hazard, area with High flow accumulation signifies high flood hazard (Mahmoud & Gan, 2018). The flow accumulation map is obtained by performing GIS analysis of the digital elevation model with spatial analyst tool in ArcGIS Figure 3. The study area is dominated with areas of high flow accumulation places like ilubinri, Marina, Amadu bello in Eti-Osa LGA and some other area, from the elevation model of the study area it shows that nearly all the area received higher rate of water accumulation which makes them more prone to flood inundation Figure 3, it is seen that the flow accumulation ranges from 1 to a maximum of 128 pixels.

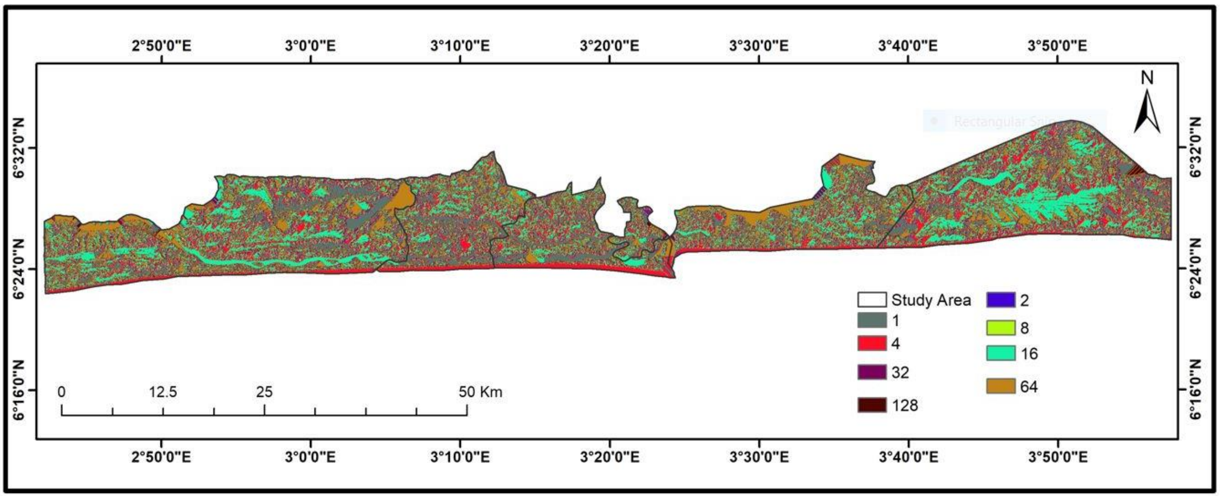

Figure 4. Flow Accumulation Map of the study area

3.4. Elevation

The elevation of a watershed is one of the factors that contributes to flood hazard in that watershed (Chakraborty & Mukhopadhyay, 2019). The highest elevation in the watershed is 40m while the lowest elevation is -6m. The lowest elevation class was rated as very high flooding hazard class whereas the highest elevation class is rated as very low flood hazard class. It is shown in Figure 4 that the lower elevations are dominant in the Eti-Osa and Apapa which renders these area more prone to flooding. In general the study area can be refer to as a very low elevation area.

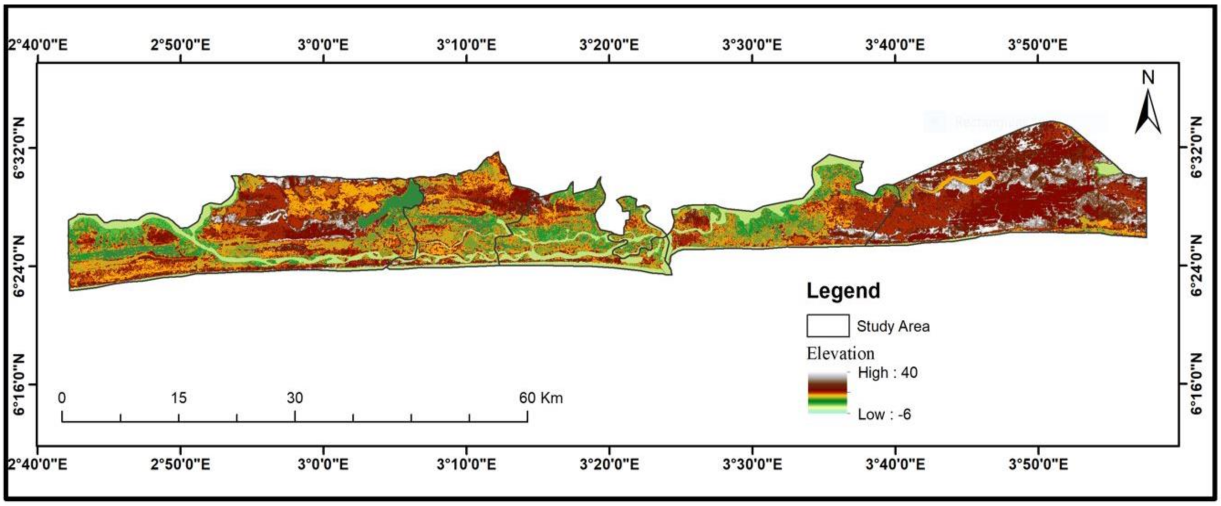

Figure 5. Elevation Map of the study area

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3.4.1. Rainfall

Rainfall is one of the most prominent factor in flooding. When there is an event of high down pour, there is high likelihood of flooding if the drainage system is incapable to accommodate the run-off water in an area. In this study, the true reflection of intense rainfall in Badore (Lekki) and Victoria Island (Eti-Osa) shows that very high rainfall amounts of over 2200mm annually are recorded.. Areas northeast of Victoria Island and Lekki experience relatively low rainfall amounts of below 2000mm annually.

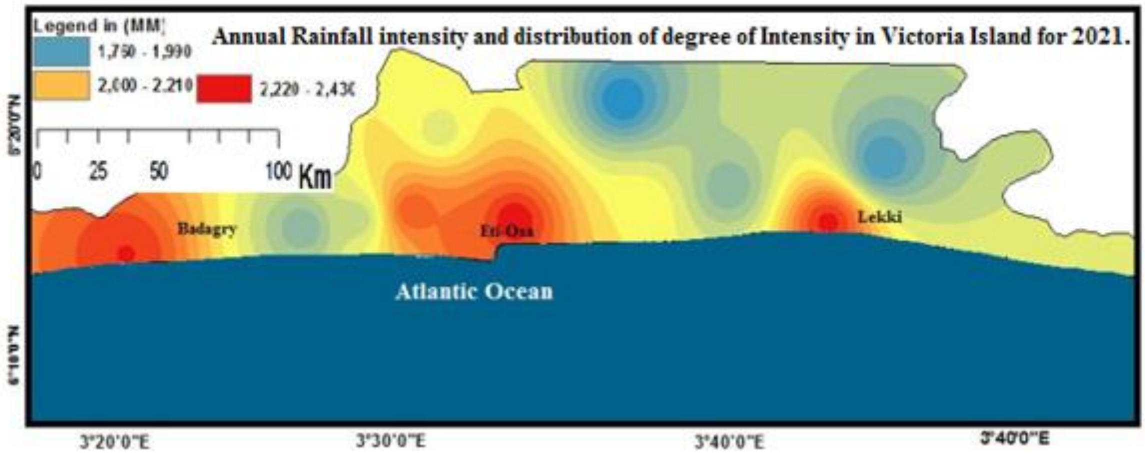

Figure 6. Distribution of Annual rainfall (Intensity) in Lagos 2021

Figure 7 shows the 3D elevation of the study area. The blue colour on the map show different scenario of sea level sea level at 2m and 5m above the sea. A situation where by the sealev rise to the stated level about half of the state will be washed away.

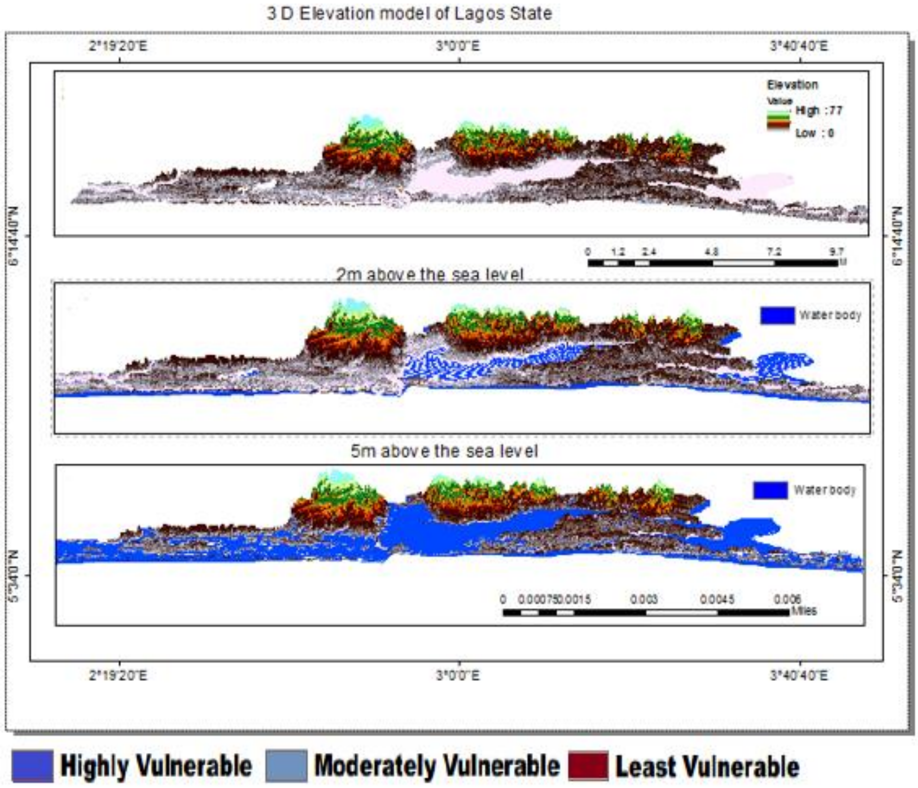

Figure 7. Area vulnerable to rise in water level

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4. CONCLUSION AND RECOMMENDATION

This study have been able to demonstrate the capability of geospatial technique in the area of flood mapping due to excessive rainfall and rise in water level. The outcome of the study shows areas in Lagos State that are highly vulnerable to flooding, moderately vulnerable and least vulnerable. The result of the study revealed that area such as Eti-Osa, Badagry, Apapa Amuwo, Ojo and the surrounded area are highly vulnerable. For proper management and mitigation of flood disaster in the study area, the policy makers both private and government should put in place proper emergency response measures to curb the impact of flood on the communities. Proper town planning should be enforced to discourage residents or investors from indiscriminate usage of land such as farming, building construction etc., which could exposed the mentioned local government area to flood vulnerability. Construction of embankments in needed area of the local government should be done, in addition; proper channelization of water ways should be done to reduce flooding in the study area.

Declarations

Source of Funding

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this research work.

References

Alwang, J., Siegel, P. B., & Jorgensen, S. L. (2001). Vulnerability: a view from different disciplines. Social protection discussion paper series, Vol. 115, p. 60.

Adelekan I.O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environ and Urban, 22: 443–450.

Akinsanya CK (2003). Recent trends in the pollution load on the Lagos Lagoon - Lagos State perspective. A paper presented on ecological sustainable industrial development workshop organized by UNIDO, pp. 2–17.

Bates, P. D., and De Roo, A. P. J. (2000). A simple raster-based model for flood inundation simulation. J. Hydrol., 236: 54–77. DOI: 10.1016/S0022-1694(00) 00278-X.

Maplecroft (2012). World's fastest growing populations increasingly vulnerable to the impacts of climate change – 4th global atlas reports. Available from: http://maplecroft.com/about/news/ccvi_2012.html [Accessed 4/09/2020].

Charvériat, C. (2000). Natural disasters in Latin America and the Caribbean: An overview of risk.

National Oceanic and Atmospheric Administration [NOAA] (2010). Technical considerations for use of geospatial data in sea level change mapping and Assessment," in NOAA Technical Report NOS 2010-01, (Silver Spring, MD: NOAA).

Gallien, T. W., Schubert, J. E., and Sanders, B. F. (2011). Predicting tidal flooding ofurbanized embayments: a modeling framework and data requirements. Coast. Eng., 58: 567–577. DOI: 10.1016/j.coastaleng.2011.01.011.

Habel, S., Fletcher, C. H., Rotzoll, K., and El-Kadi, A. I. (2017). Development of a model to simulate groundwater inundation induced by sea-level rise and high tides in Honolulu, Hawaii. Water Res., 114: 122–134. DOI: 10.1016/ j.watres.2017. 02.035.

Croitoru, Lelia; Chang, Jiyoun Christina; Kelly, Andrew (2020). The Cost of Air Pollution in Lagos. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/33038 License: CC BY 3.0 IGO."